Island County 2023 Shoreline Armor Survey – Approach and Phase 1 Results

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TECHNICAL MEMORANDUM

Date: December 21, 2023
To: Kelly Zupich, Island County Public Health Natural Resource Specialist
Copy to: Island County Marine Resources Committee
From: Lauren Ode-Giles and Andrea MacLennan, Herrera Environmental Consultants, Inc.
Subject: Island County 2023 Shoreline Armor Survey – Approach and Phase 1 Results

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2200 Sixth Avenue, Suite 1100 | Seattle, WA 98121 206.441.9080 herrerainc.com
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Executive Summary

Herrera Environmental Consultants, Inc. (Herrera) conducted boat-based mapping of the shorelines of Whidbey and Camano Islands on behalf of the Island County Marine Resources Committee (MRC) to document the presence of hard shoreline armor across the county. The results of this shoreline armor mapping were compared to the results of a similar mapping effort completed in 2016, to identify where shoreline armor had potentially been added across the 7-year period between 2016 and 2023.

Although the results document a very minor net change in the length of shoreline armor, this is largely attributed to the considerable length of armor removal (2.3 miles) that has occurred in the county. Preliminary results of the change analysis identified approximately 285,660 feet (54.1 miles or 25.3 percent of the Island County shoreline) as having hard armor in 2023, relative to 284,000 feet (53.8 miles or 25.2 percent of the shoreline) from 2016 mapping. This constitutes a net increase of approximately 1,770 feet (0.3 mile) of mapped shoreline armor between the 2016 and 2023 mapping efforts. An estimated 14,100 feet (2.7 miles) of armor were added to the shorelines of Island County since 2016, with approximately 12,400 feet (2.3 miles) of armor removed or lost since 2016 mapping.

This preliminary change analysis was concerned with identifying areas where shoreline armor had been mapped in 2023 but not in 2016. Phase 2 of the change analysis will identify where armor was likely added between 2016 and 2023 and will evaluate whether development permits were issued in accordance with armor that was added to the shoreline over that period.

Approach

Field Methods

Field-based data collection was conducted over 11 field days between September 18 and October 19, 2023. Mapping was conducted by boat in teams of two experienced coastal scientists following the shoreline armor mapping methods described in *Armor Mapping Methods for the Puget Sound Region* (CGS, 2018) (CGS 2018). All team members reviewed methods for interpreting coastal conditions and assigning shoreline armor characteristics prior to initiating field work (Figure 1). All data capture and entry was carried out by the same coastal geospatial scientist to maximize consistency.

Figure 1. Representative Examples of Shoreline Armor Encountered on Whidbey and Camano Islands.

Concrete Bulkhead with Derelict Vertical Wood Piles	Stacked Rock Revetment	Creosote-Treated Wooden Bulkhead Adjacent to a Metal Sheet-Pile Wall

Mapping was conducted using an EOS Arrow 100 sub-meter GPS unit with real-time kinematic (RTK) corrections (Figure 2.1), which received virtual offsets from a linked LaserTech TruPulse 360-series laser rangefinder (Figure 2.2). A TruPulse 360B laser rangefinder was used during the first 8 days of data collection, and a TruPulse 360R was used for the final 3 days of mapping. Laser rangefinders were calibrated following manufacturer guidelines at the beginning of each field day, and the accuracy of the laser rangefinder was periodically evaluated across each day.

Figure 2.1. EOS Arrow 100 GPS Receiver and Antenna Mounted to the Field Boat.	Figure 2.2. Field Staff Conducting Offset Mapping Using a TruPulse 360-Series Laser Rangefinder and Esri FieldMaps Application.
	

To promote data collection efficiency and to reduce opportunities for transcription error and data loss, digital field forms constructed in ArcGIS FieldMaps were used in lieu of printed field forms. The same shoreline armor attributes as described in CGS (2018) were documented in this mapping effort (material composition, tidal elevation, armor condition, other notes). The use of ArcGIS FieldMaps also allowed field staff to view the presence of armor from the previous 2016 mapping effort while conducting data collection and check for consistency.

Other constructed coastal features of interest, including boat ramps, boat houses, and chained/anchored logs were mapped as single GPS points during field data collection. These points were reviewed and augmented with high-resolution aerial photographs following field-based data collection in the same manner as shoreline armor points. Since these other features were not the focus of this 2023 mapping effort, no warranty is made regarding the completeness of this supplemental feature layer.

Data Review

Review and quality control of mapped data was conducted at several stages across the project. During initial data collection, the placement of GPS-offset, shoreline armor points was visually inspected in real-time using the FieldMaps application, because aerial photographs in the application and previously mapped armor from the 2016 mapping event could be viewed to confirm that relative point placement was occurring as expected.

Following initial data collection, mapped armor points were reviewed in Esri ArcGIS Pro for completeness, accuracy, and consistency of mapped points and attributes. In all instances where shoreline armor was mapped in 2016 but was not observed in 2023, high resolution aerial photography (Island County Oblique Viewer 2020) was reviewed to confirm the absence of shoreline armor.

In limited instances where the nearshore was too shallow to allow for direct placement of GPS-offset points on shoreline armor, GPS points were placed offshore and positioned in desktop analysis based on field photographs and review of high-resolution aerial photographs. The interior of private marinas and shallow coves were not subject to mapping updates in this 2023 analysis. Armor attributes in these areas were copied from the 2016 mapping event.

Data Processing

Mapping was conducted using an EOS Arrow 100 sub-meter GPS unit with RTK corrections, which did not require additional differential corrections in postprocessing.

Following review and validation of all mapped shoreline armor points, GPS-collected and remotely mapped armor attributes were processed from individual armor vertices into polyline features in ArcGIS Pro. Herrera applied a semi-automated approach. This was intended to improve data production efficiency, based on the approach described in CGS (2018). Rather than manually digitizing each armor segment from mapped offset points, each point was assigned a sequential identifying number derived from the alongshore direction in which mapping was conducted. A section of continuous armor would be composed of increasing ID numbers from start to end. For example, a section would include the ID numbers "347, 348, and 349" to represent a set of three points: "start, change, and end" (see Figure 3). After ID numbers were assigned, armor segments were automatically generated using the "points to lines" geospatial processing tool, with the attributes of each armor segment being assigned from the leading point in the sequence. Lines generated with an "end"-type point as their origin were deleted, since these represented areas with no shoreline armor.

Figure 3. Example of Armor Lines Generated Using Sequentially Assigned Identifiers, with Attributes Populated from Start to End.

After lines were generated to describe the extent of shoreline armor from offset-mapped points, the length of each armor segment was populated to a new "pre-snap armor length" field. This allowed for preservation of initial armor extents prior to conforming to the WDNR ShoreZone Shoreline (Berry et al. 2001).

Other mapped features, including the presence of boat ramps, cabled logs, and other noted features were visually reviewed from high-resolution aerial photographs and exported as points to separate geospatial feature classes.

Data products produced from this analysis include:

- Armor lines and attributes mapped in 2023 (including a pre-snap length field), conforming to the ShoreZone Shoreline (discontinuous line segments, mapping only where armor was present)
- A merged layer containing complete ShoreZone Shoreline geometry (continuous), including amor lines and attributes mapped in 2023 and a field indicating whether armor was present in 2016 and 2023 for direct comparison (does not include pre-snap length field)
- Other layers
  - Boat ramps
  - Cabled logs and other features of note

Figure A.1 (Appendix A) depicts the full extent of shoreline armor mapped in Island County in 2023. A full description of the attributes associated with each geospatial feature class is included in Appendix B.

A merged layer containing complete ShoreZone Shoreline geometry, the presence and attributes of armor in 2016 and 2023, and pre-snap armor lengths for 2023 and 2016 was not produced as part of this Phase 1 effort.

Change Analysis

A detailed evaluation of countywide changes in shoreline armor is planned for a second phase of this effort that is anticipated in 2024. A preliminary, targeted evaluation was conducted in this first phase to identify where armor was not mapped in 2016 but was mapped in 2023.

The total length of shoreline armor mapped in Island County can be compared between 2016 and 2023 using either the pre-snap armor length attributes (as described in the Data Processing section of this memorandum) or the post-snap (ShoreZone Shoreline-conforming) measurement. Both measurement methods were applied to identify net differences in shoreline armor presence between the 2016 and 2023 mapping events.

A minimum margin of acceptance for mapping errors/comparisons between the ShoreZone Shoreline-conforming measurements in the merged 2016 and 2023 geospatial layer was set at 5 feet. This is based on the cumulative error of:

- The median horizontal root mean squared (HRMS) error of the Arrow 100 RTK GPS unit plus two standard deviations: 0.52 foot + (0.61 foot * 2) = 1.73 feet
- The accuracy of the TruPulse 360-series laser rangefinder for a low-quality target: +/-3 feet

This produced a cumulative error of 4.73 feet, which was rounded to 5 feet as a cautious minimum margin of acceptance.

This minimum margin of acceptance is considered separately from the 20-foot minimum mapping unit described in the armor mapping methods. The minimum mapping unit serves as a threshold under which shoreline armor is not included in the mapping dataset. The minimum margin of acceptance is applied to filter out areas of minimal change (within the potential error margin of the mapping technology) between armor mapping results in 2016 and 2023.

Results

The objective of this preliminary change analysis was focused on identifying where coastal armor was mapped in 2023 but was not mapped in 2016. Changes in the mapped presence of armor may be the combined results of:

- Installations of new shoreline armor since the 2016 mapping event, including extensions of the footprint of existing shoreline armor
- Incomplete mapping of shoreline armor in 2016 (especially where armor was derelict, where weather and tides precluded direct shore observation, and/or where visual obstructions to armor were present such as overhanging vegetation, piled drift logs, backshore vegetation, etc.)
- Differences in the interpretation of shoreline armor origin/end points based on the availability of higher-resolution aerial photography relative to the 2016 mapping event (where remote mapping and/or remote validation of armor placement occurred)

A summary of the mapped presence of shoreline armor in 2016 and 2023 is presented in Table 1. This summary table includes both measures of pre-snap and post-snap armor lengths (as described in the Data Processing section). The reported pre-snap armor length is less than the reported post-snap armor length for both 2016 and 2023 shoreline armor mapping. While the pre-snap lines represent accurate placement of the GPS-mapped armor positions along the shoreline, the resultant lines have a simpler shoreline geometry than the ShoreZone Shoreline. Additionally, differences in the placement of GPS-mapped points alongshore can substantially alter the resultant pre-snap armor lengths, especially in areas of continuous, relatively uniform armor composition (Figure 4). For these reasons, the post-snap armor lengths will be used for reporting change in this Phase 1 report (subject to the 5-foot minimum margin of acceptance).

Table 1. Summary of Mapped Shoreline Armor, 2023 and 2016.

Mapped Armor Presence	Armor Length, 2016 (feet/percent of county shoreline)	Armor Length, 2023 (feet/percent of county shoreline)
Total pre-snap armor length	280,744 (24.9 percent)	276,614 (24.5 percent)
Total post-snap armor length[a,b]	283,893 (25.2 percent)	285,662 (25.3 percent)
Length of armor present in both 2016 and 2023[a,b]	271,527 (24.0 percent)	
Length of armor present only in 2016 or only in 2023[a,b]	12,366 (1.1 percent)	14,136 (1.3 percent)
Difference in armor length, 2023–2016[a,b]	1,770 (0.1 percent)	

[a] Shoreline armor segments with a length of less than 5 feet were considered to be below the margin of spatial error for change detection and were omitted when summarizing ShoreZone-conforming armor lengths.

[b] This calculation references the ShoreZone Shoreline-conforming (post-snap) armor length, not the pre-snap armor length.

Figure 4. Example of Difference in GPS Point Placement in 2016 and 2023 Mapping Efforts Relative to the ShoreZone Shoreline that Produced Different Pre-Snap Shoreline Armor Measurement Results.

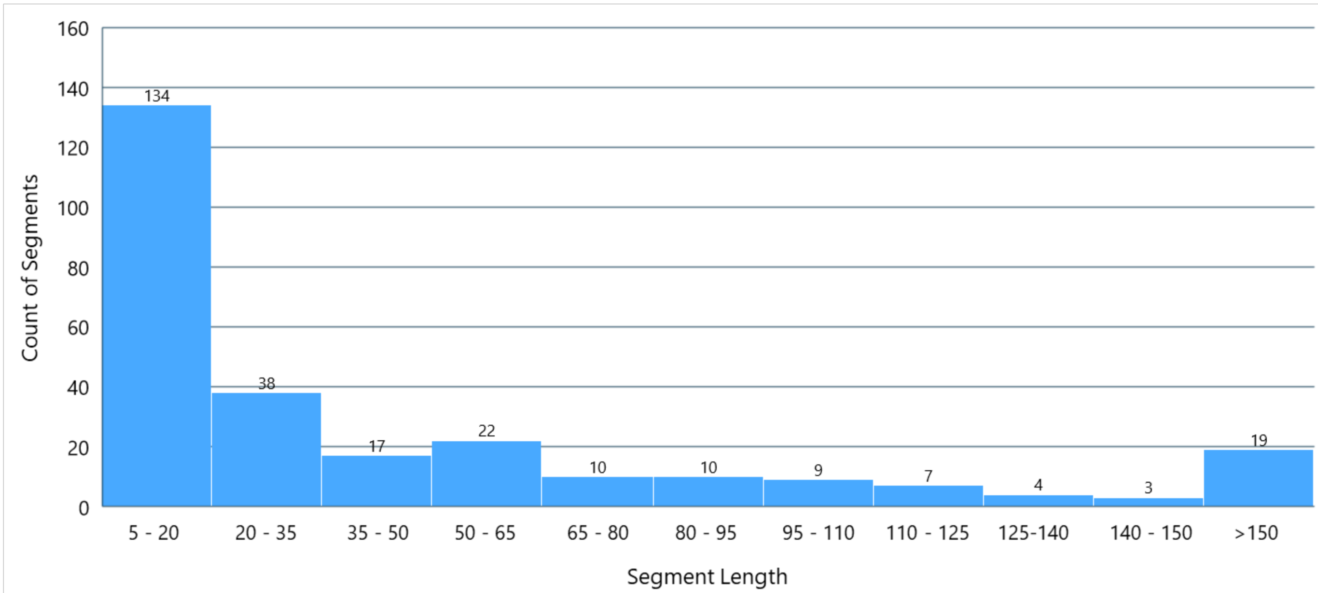
Based on the post-snap armor length measurements, approximately one-quarter (25 percent) of Whidbey and Camano Islands were armored in 2016 and 2023 (Table 1). Approximately 271,530 feet (51.4 miles) of shoreline armor was mapped as being present in both 2016 and 2023 mapping, with an additional approximately 12,370 feet (2.3 miles) of armor present in 2016 that was not mapped as present in 2023, and approximately 14,140 feet (2.7 miles) of armor present in 2023 that was not mapped in 2016 (Table 1). This represents a net increase in shoreline armor of 1,770 feet (0.3 mile) between 2016 and 2023 (Table 1).

A total of 308 shoreline armor segments were mapped in 2016 but not in 2023, representing a potential loss of armor. Of those, 111 segments had a length of less than 5 feet and were screened out of the preliminary change analysis results. Of the remaining 197 armor segments mapped only in 2016, 80 (41 percent) had a post-snap length between 5 and 20 feet, and 117 (59 percent) had a length greater than 20 feet.

Of the 391 shoreline armor segments mapped only in 2023 but not in 2016 (representing a potential addition of armor), 118 were screened out for having a length less than 5 feet, leaving 273 segments of potential new armor. Of these, 134 (49 percent) had a length between 5 to 20 feet, 55 (20 percent) had a length between 20 and 50 feet, and 84 (30 percent) had a length greater than 50 feet (Figure 5). The spatial distribution of potential new armor segments by length is explored in Figure A.4.

Figure 5. Distribution of the Lengths of Potential New (present in 2023 but not in 2016) Shore Armor Segments.

Armor segments with a length of less than 5 feet were omitted.



A subset of segments where there was a potential change in armor presence between 2016 and 2023 (gain or loss) was spot-checked against aerial photographs to understand the potential nature of change. Twenty segments were checked (4 percent of change segments >5 feet), with lengths ranging from 5.1 and 448 feet. Nine of the checked segments (45 percent) appeared to represent areas of real on-the-ground change between 2016 and 2023 conditions. Seven of the checked segments (35 percent) appeared to be the result of differences in alignment of the post-snap armor extents. This brief review could not determine whether four change segments (20 percent) were the result of actual differences in mapped conditions.

The spatial distribution of armor that was mapped in 2023 but not in 2016 was relatively uniform across Whidbey and Camano Islands, though Camano and southern Whidbey Island did have relatively more of this armoring than central and northern Whidbey Island (Appendix A, Figure A.3). A visual review of the armor segments mapped in 2023 but not in 2016 appeared to indicate that a number of these newly mapped segments represented infilling of previously unarmored sections of shoreline between neighboring armored properties. Others appeared to represent extensions and reconfigurations of existing armor footprints since the 2016 mapping event. A more detailed evaluation of the source and nature of differences in armor mapping between 2016 and 2023 will be provided in Phase 2.

It is important to emphasize that this preliminary analysis alone does not conclude that armor was added between 2016 and 2023 in all cases for the reasons previously described. In instances where new armor was known to have been constructed between 2016 and 2023, this preliminary analysis does not evaluate whether the armor was associated with appropriate permits. This analysis also does not capture soft shore installations, as these can be challenging to visually identify. However, cabled logs were mapped separately, where observed, and are included in the "other features" geospatial file.

Phase 2

This preliminary analysis was solely concerned with how much more armor was mapped in 2023 relative to 2016. Phase 2 of this analysis (anticipated in 2024) will evaluate where the mapped presence of armor changed between 2016 and 2023, potential causal mechanisms associated with those changes in the mapped presence of armor (i.e., was armor missed in 2016 but mapped in 2023? Was armor removed or added between 2016 and 2023? Was existing armor extended or augmented between 2016 and 2023?). Phase 2 will also evaluate whether permits were issued in association with the development of new shoreline armor.

References

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Island County Oblique Viewer. 2020

MacLennan, A., J. Johannessen, and A. Lubeck. 2018. Armor Mapping Methods for the Puget Sound Region. CGS, Bellingham, Washington.

Appendix A

Shoreline Armor Map Folio

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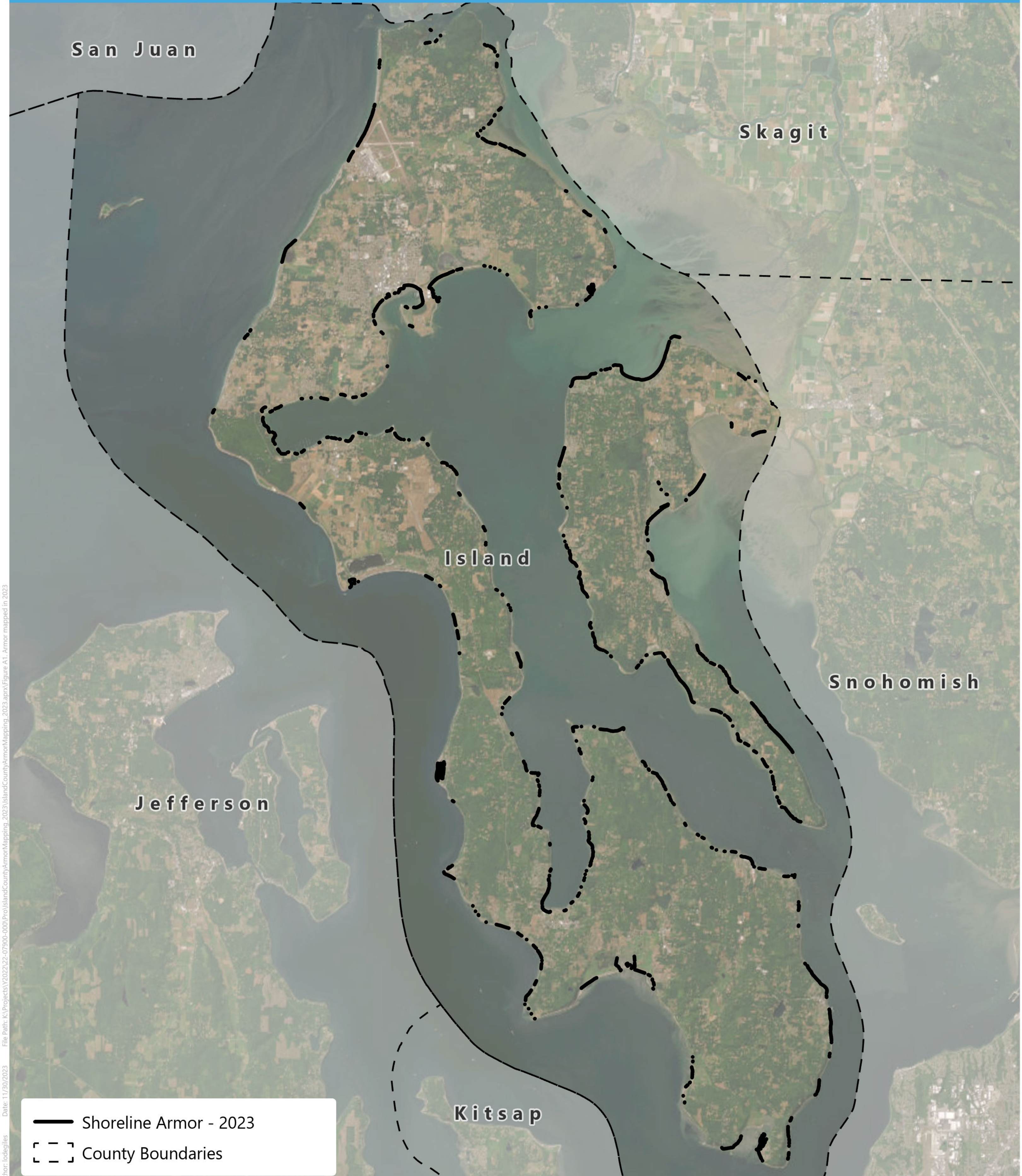
Figure A.1. Mapped presence of shoreline armor in Island County, WA - 2023.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources:

Author: lodegiles Date: 11/30/2023 File Path: K:\Projects\Y2022\22-07900-000\Pro\IslandCountyArmorMapping_2023\IslandCountyArmorMapping_2023.aprx\Figure A1. Armor mapped in 2023

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Figure A.2. Mapped presence of shoreline armor in Island County, WA - 2016.

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Figure A.3. Shoreline Armor in Island County, WA, Mapped only in 2023 (not mapped in 2016).

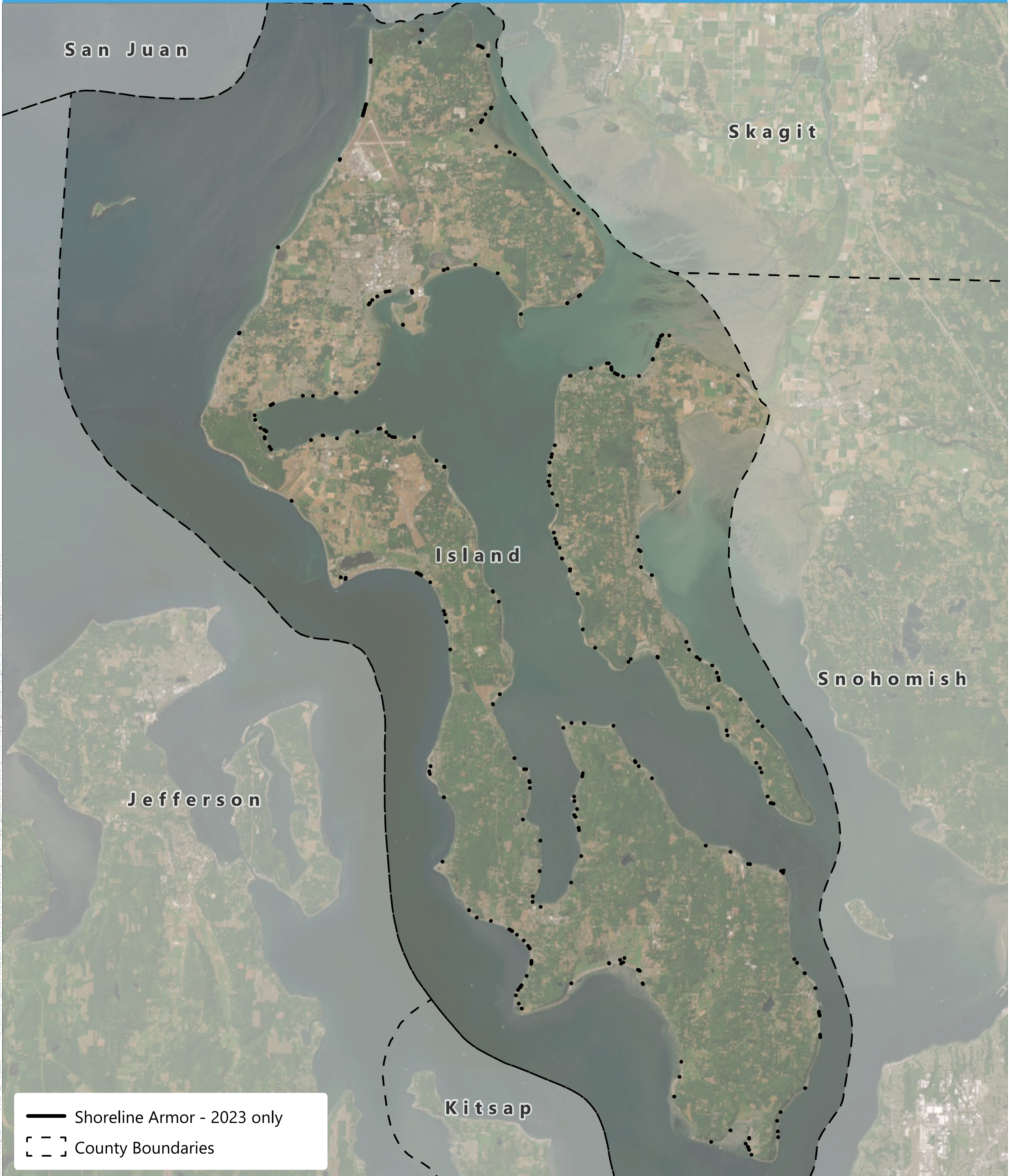

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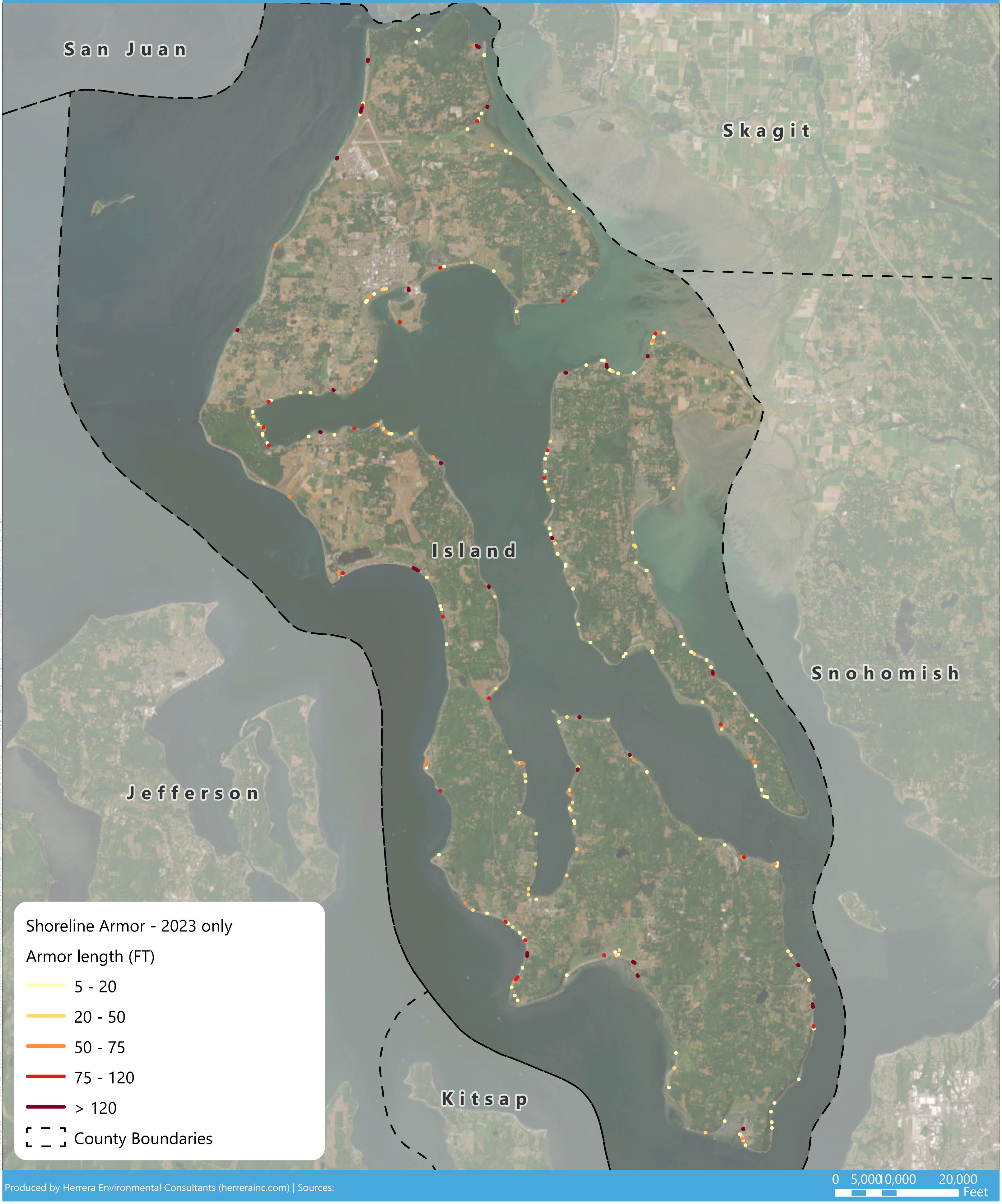
Figure A.4. Shoreline Armor in Island County, WA, Mapped only in 2023 (not mapped in 2016), by Length.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources:

Figure A.5. Shoreline Armor in Island County, WA, Mapped only in 2016 (not mapped in 2023).

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Appendix B

Mapped Armor Geospatial Attributes – 2023

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This appendix describes the feature class attributes associated with geospatial deliverables for the Island County Shoreline Armor Mapping Phase 1 geodatabase.

Table B-1. Geospatial Attribute Table Field Names, Field Types, and Descriptions for the ICAM_ShorelineArmor_2023 Feature Class.

Field Name	Data Type	Description
ObjectID	Object ID	Automatically generated field with unique object identifier
MappingMethod	Text	Distinguishes between features mapped using field or remote methods
Armored	Boolean	Presence of armor (0 = no armor; 1 = armor)
ArmorRock	Boolean	Armor includes rock material (0 = no rock; 1 = includes rock)
ArmorConcrete	Boolean	Armor includes concrete material (0 = no concrete; 1 = includes concrete)
ArmorWood	Boolean	Armor includes wood material (0 = no wood; 1 = includes wood)
ArmorWoodCreosoted	Boolean	Armor includes creosote-treated wood material (0 = no creosote-treated wood; 1 = includes creosote-treated wood)
ArmorOther	Boolean	Armor includes other material types not otherwise specified (0 = no other material; 1 = includes other material)
ArmorElevation	Text	Relative tidal elevation of armor (U = Above extreme high water (upland); D = Ordinary high water mark to extreme high water (dunegrass area); HW = Mean higher high water to ordinary high water mark; Below_HW = Mean sea level to mean higher high water; SL = Below or at sea level)
ArmorCondition	Text	Armor condition (Ok = no signs of failure; F = Functional but failing; D = Derelict)
ArmorNotes	Text	Additional notes related to armor mapping, material composition, etc.
CreationDate	Date	Date on which associated armor vertex was mapped
Creator	Text	User account associated with vertex mapping
EditDate	Date	Date on which associated armor vertex was last edited
Editor	Text	User account associated with last vertex edit
SegmentType	Text	Associated origin point of armor from field or remote mapping (Start = beginning of mapped armor segment; Change = Change in composition of armor)
PreSnapLenFT	Numerical	Length of armor segment prior to snapping and conformation with the WDFW ShoreZone Shoreline dataset
Shape_Length	Numerical	Automatically generated field; length of line feature in feet

Table B-2. Geospatial Attribute Table Field Names, Field Types, and Descriptions for the ICAM_ShorelineArmor_2016_2023_Comparable Feature Class.

Field Name	Data Type	Description
ObjectID	Object ID	Automatically generated field with unique object identifier
MappingMethod	Text	Distinguishes between features mapped using field or remote methods
Armored	Boolean	Presence of armor (0 = no armor; 1 = armor)
ArmorRock	Boolean	Armor includes rock material (0 = no rock; 1 = includes rock)
ArmorConcrete	Boolean	Armor includes concrete material (0 = no concrete; 1 = includes concrete)
ArmorWood	Boolean	Armor includes wood material (0 = no wood; 1 = includes wood)
ArmorWoodCreosoted	Boolean	Armor includes creosote-treated wood material (0 = no creosote-treated wood; 1 = includes creosote-treated wood)
ArmorOther	Boolean	Armor includes other material types not otherwise specified (0 = no other material; 1 = includes other material)
ArmorElevation	Text	Relative tidal elevation of armor (U = Above extreme high water (upland); D = Ordinary high water mark to extreme high water (dunegrass area); HW = Mean higher high water to ordinary high water mark; Below_HW = Mean sea level to mean higher high water; SL = Below or at sea level)
ArmorCondition	Text	Armor condition (Ok = no signs of failure; F = Functional but failing; D = Derelict)
ArmorNotes	Text	Additional notes related to armor mapping, material composition, etc.
Armored16	Boolean	Armor was mapped as present in 2016 (0 = no armor mapped in 2016; 1 = armor mapped in 2016)
Armored23	Boolean	Armor was mapped as present in 2023 (0 = no armor mapped in 2023; 1 = armor mapped in 2023)
SegmentType	Text	Associated origin point of armor from field or remote mapping (Start = beginning of mapped armor segment; Change = Change in composition of armor)
CreationDate	Date	Date on which associated armor vertex was mapped
Creator	Text	User account associated with vertex mapping
EditDate	Date	Date on which associated armor vertex was last edited
Editor	Text	User account associated with last vertex edit
Shape_Length	Numerical	Automatically generated field; length of line feature in feet

Table B-3. Geospatial Attribute Table Field Names, Field Types, and Descriptions for the ICAM_BoatRamps Feature Class.

Field Name	Data Type	Description
ObjectID	Object ID	Automatically generated field with unique object identifier
MappingMethod	Text	Distinguishes between features mapped using field or remote methods
BoatRamp	Boolean	Presence of boat ramp (0 = no boat ramp; 1 = boat ramp)
RampRock	Boolean	Boat ramp includes rock material (0 = no rock; 1 = includes rock)
RampConcrete	Boolean	Boat ramp includes concrete material (0 = no concrete; 1 = includes concrete)
RampWood	Boolean	Boat ramp includes wood material (0 = no wood; 1 = includes wood)
RampWoodCreosoted	Boolean	Boat ramp includes creosote-treated wood material (0 = no creosote-treated wood; 1 = includes creosote-treated wood)
RampOther	Boolean	Boat ramp includes other material types not otherwise specified (0 = no other material; 1 = includes other material)
RampElevation	Text	Relative tidal elevation of boat ramp (U = Above extreme high water (upland); D = Ordinary high water mark to extreme high water (dunegrass area); HW = Mean higher high water to ordinary high water mark; Below_HW = Mean sea level to mean higher high water; SL = Below or at sea level)
RampCondition	Text	Boat ramp condition (Ok = no signs of failure; F = Functional but failing; D = Derelict)
FeatureNotes	Text	Additional notes related to boat ramp mapping, associated features, etc.
GlobalID	Text	Automatically generated field with Global ID; links boat ramp points to field photographs
CreationDate	Date	Date on which associated boat ramp was mapped
Creator	Text	User account associated with boat ramp mapping
EditDate	Date	Date on which associated boat ramp was last edited
Editor	Text	User account associated with boat ramp edit

Table B-4. Geospatial Attribute Table Field Names, Field Types, and Descriptions for the ICAM_OtherFeatures Feature Class.

Field Name	Data Type	Description
ObjectID	Object ID	Automatically generated field with unique object identifier
MappingMethod	Text	Distinguishes between features mapped using field or remote methods
Armored	Boolean	Presence of armor (0 = no armor; 1 = armor)
ArmorRock	Boolean	Armor includes rock material (0 = no rock; 1 = includes rock)
ArmorConcrete	Boolean	Armor includes concrete material (0 = no concrete; 1 = includes concrete)
ArmorWood	Boolean	Armor includes wood material (0 = no wood; 1 = includes wood)
ArmorWoodCreosoted	Boolean	Armor includes creosote-treated wood material (0 = no creosote-treated wood; 1 = includes creosote-treated wood)
ArmorOther	Boolean	Armor includes other material types not otherwise specified (0 = no other material; 1 = includes other material)
FeatureElevation	Text	Relative tidal elevation of armor/associated feature (U = Above extreme high water (upland); D = Ordinary high water mark to extreme high water (dunegrass area); HW = Mean higher high water to ordinary high water mark; Below_HW = Mean sea level to mean higher high water; SL = Below or at sea level)
FeatureCondition	Text	Feature condition (Ok = no signs of failure; F = Functional but failing; D = Derelict)
FeatureNotes	Text	Additional notes related to other feature mapping, material composition, etc.
GlobalID	Text	Automatically generated field with Global ID; links feature points to field photographs
CreationDate	Date	Date on which feature was mapped
Creator	Text	User account associated with feature mapping
EditDate	Date	Date on which associated feature was last edited
Editor	Text	User account associated with feature edit